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SEWAGE DEMONSTRATION PLANT AT GLENWOOD, MINNESOTA

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ANNUAL PROGRESS REPORT ON THE SEWAGE DEMONSTRATION PLANT AT GLENWOOD, MINNESOTA

The purpose of the demonstration plant at Glenwood was to determine whether or not the Oxidation Channel type of sewage treatment as developed in Holland will remove more of the plant nutrients from the effluent than is possible with the more conventional types of sewage treatment. One of the principle investigators (Halvorson) visited a number of these plants in Europe and came to the conclusion that these plants had the unique feature of assimilating much of the nitrogen and phosphate into microbial protoplasm that could be removed from the system before these ingredients were again released into solution through a breakdown or decomposition of the microorganisms involved.

As a result of the impressions that Halvorson gained in Europe, he initiated some laboratory studies at the University of Illinois in which he tested the idea of whether or not microorganisms could assimilate the nitrogen and some of the phosphate present in the sewage liquid and sewage solids into their protoplasm so that they could be removed from the liquid. He did this by subjecting sludge from the primary settling tank at Urbana, Illinois to aerobic digestion in a glass jar having a capacity of 20 liters. The results of these studies were very encouraging. They showed that under proper conditions of aeration and with a suitable detention of the solids it was possible to produce an effluent that not only had a very low B.O.D., but also one in which there was present only traces of dissolved nitrogen. The effluent also contained much less phosphate than was present in the starting material.

These studies were continued by one of his graduate students (Dr. Irgens) who used these studies for his Ph.D. dissertation. The results of these studies were published (Irgens and Halvorson, 1965).

After the laboratory studies had been completed it was deemed desirable to test the principle in an actual plant. After a survey of a number of locations it was decided to approach the city of Glenwood, Minnesota to see if a plant could

be built there. This city was selected because it discharges its effluent into a lake and it is the only city that does discharge a sewage effluent into this lake. During the last few years algae growth has become more and more prevalent in the lake during the summer months - so much so that the recreational use of the lake has been threatened. This has been aggravated to some considerable extent by the inadequacy of the sewage treatment at Glenwood. The city had an old trickling filter plant that was in a bad state of repair and was too small for the present community. The city needed to build a new plant. The city agreed to build the plant modeled after the European type of oxidation channel. This was done and the plant was put into operation July, 1964.

A request was made to the NIH for funds to equip a laboratory at Glenwood and to employ the necessary personnel to make studies on the operation of the plant. It had been planned to start these studies shortly after the plant was put into operation but unavoidable delays prevented this. In the first place funds from the NIH could not be made available at that time and after the funds did become available it took several months before the laboratory equipment could be delivered and installed. After several months of delay the studies were started in July, 1965. The following is a report of the results that have been obtained since that time.

Prior to the design of the plant it was necessary to measure the flow of sewage in the city and determine its strength. The population of Glenwood at that time was about 2,500. Thus with some small amount of industrial waste it was decided to design the plant for a population of 4,200 persons. The flow of sewage as measured at that time was about 240,000 gallons per day. The plant was therefore designed to handle a flow of 450,000 gallons. During the first year of operation before our studies were inaugurated the flow of sewage was within the volumes that had been measured. During the first year of operation after our studies were started the area around Glenwood had an unusual amount of rainfall and a substantial

amount of storm water found its way into the sanitary sewers. As a result the flow of sewage during this first summer of our studies were very high - some days over 1,000,000 gallons per day. We had hoped that this was a temporary situation and that smaller flows would be occurring during the fall and winter months when there would be little opportunity for storm water to get into the sanitary sewers. This proved not to be the case. Very heavy flows have continued all through the winter and the flow has never been down to the design figures. In fact it has not gotten down to the 450,000 gallons for which the plant was designed. The city has now taken steps to study the leaks into the sanitary sewers and has promised us that these will be corrected.

In spite of these heavy flows the plant has done a good job of treatment, but the high flows have prevented us from instituting the kind of studies we had hoped in order to determine the best method of operation to give the minimum amount of plant nutrients in the final effluent. This will be revealed in the data to follow.

Description of the Laboratory

The laboratory was equipped with furniture supplied by the Hamilton Company, Two Rivers, Wisconsin. The laboratory has 23 feet of 30 inch high workbench with three kneeholes and 12 feet of 36 inch high workbench with two large sinks and one cupsink. The laboratory also has a hood. Below the hood is an oven for drying glassware. The laboratory is supplied with outlets for compressed air and gas. It has two cabinets mounted on the wall for glassware and one large, double cabinet standing on the floor.

The laboratory contains the following pieces of major equipment: drying oven, 2 incubators, water bath, Sartorius balance, clinical centrifuge, muffle furnace, sterilizing oven, autoclave, vacuum pump, dissolved oxygen analyzer,

refrigerator, water still, spectrophotometer, microscope, portable pH meter, and a microkjeldahl digestion apparatus.

In the laboratory is also the control panel for all the electrical plant equipment such as sewage pumps, aeration rotors, etc.

Laboratory Tests Performed and Procedures

At the Glenwood plant we have two automatic samplers, one for the raw sewage and one for the plant effluent. The automatic samples were adjusted to take one sample every half hour. The size of the sample is proportional to the flow.

The following determinations were performed according to Standard Methods: biochemical oxygen demand, chemical oxygen demand, ammonia, organic, nitrate, nitrate nitrogen, total solids, volatile solids, and settleable solids.

To determine the BOD and the dissolved oxygen in the ditch we employed a galvanic cell oxygen analyzer with a silver-lead electrode. The electrode was standardized by the Winkler method every day it was used. The samples of the raw sewage were usually diluted 1:30 and the samples for the effluent were diluted 1:4. It was found that nitrification took place in the BOD bottles with the effluent samples. To prevent this the effluent samples were pasteurized and a dilution water seeded with settled raw sewage was used.

The COD was determined by the dichromate method, and heating mantles were employed for refluxing the samples. Silver sulfate was used to improve the oxidation of straight chained alcohols and acids and mercuric sulfate was added to correct for the presence of chlorides.

Nitrate nitrogen was determined by the brucine sulfate method and the samples were filtered before the analysis was made.

Suspended solids were determined by filtration through a glass fiber filter followed by drying at 103°C for 24 hours and ashing at about 580°C for one hour.

Ammonia and organic nitrogen were determined by a modification of the micro-Kjeldahl method (Niss), and phosphate was determined by the method of Harris and Pranjivan.

Results

Table I and Figure 1 show the number of gallons of raw sewage received at the Glenwood Waste Treatment Plant over a period of 22 months. The last three months of 1964 and the first three months of 1965 show a flow that is average for a city of the size of Glenwood. However, in April, during the spring thaw, the flow increased by 10 million gallons, from 9 to 19 million. Since that time it has never dropped below 13 million, which is nearly twice the value one would expect for a city of this size.

According to flow measurements made in Glenwood before the construction of the new plant, the normal monthly flow would be 7,500,000 gallons. From table I it may be seen that this flow has only occurred once since the construction of the new plant, namely in February, 1965.

The effect of this high flow on the investigation and operation of the plant has been described elsewhere in this report.

Table 2 and Figure 2 show the hourly flow of raw sewage into the plant for June 16, 1965. The peak flow occurs at 10:00 AM and indicates that it takes the raw sewage 2 - 3 hours to reach the plant from the city. The sewage is therefore relatively fresh as it reaches the plant. This is also indicated by the presence of nitrate in the raw sewage. The water supply for the city of Glenwood contains around 5 ppm of nitrate nitrogen.

Figure 3 shows the relationship between the flow of raw sewage and the percentage removal of BOD. The graph shows very clearly that the efficiency of the removal decreases with increasing flow. This is caused primarily by the

Table 1

Monthly Flow of Raw Sewage at the Glenwood Waste Treatment Plant from June, 1964 to April, 1966

MONTH	NO. OF GALLONS
June, 1964	10,052,000
July, 1964	13,533,900
August, 1964	16,503,400
September, 1964	15,572,200
October, 1964	8,754,300
November, 1964	9,974,000
December, 1964	8,533,800
January, 1965	8,411,800
February, 1965	7,544,800
March, 1965	9,122,300
April, 1965	19,143,300
May, 1965	23,078,700
June, 1965	19,365,300
July, 1965	16,130,500
August, 1965	13,694,400
September, 1965	14,493,000
October, 1965	18,242,100
November, 1965	13,140,100
December, 1965	13,204,800
January, 1966	13,245,300
February, 1966	15,634,300
March, 1966	19,547,000

Hourly Flow of Raw Sewage - 6/16/65

Time	Flow - gallons/min.
1:00 AM	340
2:00 AM	350
3:00 AM	340
4:00 AM	350
5:00 AM	330
6:00 AM	340
7:00 AM	380
8:00 AM	420
9:00 AM	440
10:00 AM	500
11:00 AM	460
12:00 Noon	460
1:00 PM	440
2:00 PM	450
3:00 PM	450
4:00 PM	420
5:00 PM	410
6:00 PM	400
7:00 PM	410
8:00 PM	400
9:00 PM	390
10:00 PM	410
11:00 PM	410
12:00 Midnight	400

reduced detention time in the settling tank, and to some extent by a decreased detention time in the ditch. The shorter detention time in the settling tank does not give the solids sufficient time to settle in the tank, and the solids that remain in suspension leave the plant with the effluent. Too short a detention time in the ditch does not allow sufficient time for oxidation and a larger quantity of unoxidized material will enter the settling tank.

Due to the heavy infiltration the BOD of the raw sewage has remained at 100 ppm or less during the entire study. A raw sewage of this strength is more difficult to treat than one of the normal strength of 200 ppm or more.

The loss of solids in the effluent may also effect the rate of oxidation in the ditch if a sufficiently large amount of solids is lost in the effluent.

Figure 4 shows the nitrogen removal over a period of nine months. Each point on the curve represents the average of several analyses for that month. It may be seen from the graph that the nitrogen removal was largest during the month of September. The decrease from September to December is probably caused by the decreasing temperatures causing reduced microbial denitrification at that time of the year. As the population of denitrifiers is reduced during the winter months it takes time for a new population to build up. This is evident from the increasing amount of nitrogen removed from March through September. One would, however, expect that a maximum population of denitrifiers would have been reached before September. Other factors such as temperature and rainfall may also effect the nitrogen removal.

On days of heavy rain, the amount of nitrogen leaving the plant has been found to be greater than the amount of nitrogen entering the plant. This is, as has been mentioned earlier, caused by the floc leaving the plant with the effluent. A good example of this occurred on the 8th of February, 1966. The flow on that particular day was 817,200 gallons, and the amount of settleable solids in the

effluent was 15 ml, as compared to a normal amount of 1 ml or less. The quantity of nitrogen entering the plant with the raw sewage was 13 ppm and the quantity of nitrogen leaving the plant with the effluent was 19 ppm. The difference, 6 ppm, are attributed to the presence of the floc in the effluent.

The amount of phosphorus removed varied from zero to 45 percent. The monthly averages are shown in Table 3.

Table 3

Month	Average Amount of P_2 Removed - %
July, 1965	11.4
August, 1965	7.1
September, 1965	6.0
October, 1965	18.4
November, 1965	20.0
December, 1965	19.2
January, 1966	27.2
February, 1966	15.1
March, 1966	7.6

Due to delay in delivery of equipment we were not able to start analyses of total volatile solids and suspended volatile solids until January, 1966. For the months of January, February, and March the average removed was 56 percent for the suspended volatile solids and 16 percent for the total volatile solids.

Figure 5 shows the quantity of dissolved oxygen in the ditch liquor immediately following brush number one at various immersions of the brush. For the immersions shown there is a linear relationship between the dissolved oxygen and the depth of brush immersion. The dissolved oxygen would obviously approach zero at lower immersions and an upper limit at higher immersions of the brush. The most desirable

immersion being the one that would supply sufficient oxygen for the maintenance of aerobic conditions without excessive nitrification. Due to the excessively high infiltration rate, the most desirable brush depth has not been determined.

On Figure 6 is shown the oxygen uptake by the ditch solids from the time the liquor leaves one brush until it enters the following brush. The settleable solids on this particular day was 180 ml per liter after one hour of settling.

The drop of dissolved oxygen to almost zero before the liquor reaches the next brush is essential for good denitrification. In a liquor where the dissolved oxygen is high at all times, very little denitrification will occur, and as a result considerable amounts of nitrogen may be leaving the plant as dissolved nitrate in the effluent.

Table 4

Dissolved oxygen in ppm before and after each brush at various immersions of the brushes.

Brush Immersion Inches	Before Brush 1	After Brush 1	Before Brush 2	After Brush 2	Quantity* of oxygen removed during one cycle-ppm
5	0.5	1.2	0.5	1.3	1.5
6	0.6	2.0	0.8	1.8	2.4
7	1.9	3.0	1.5	2.7	2.3
8	2.7	3.8	2.5	3.9	2.5

*(DO after brush 1 - DO before brush 2) +
(DO after brush 2 - DO before brush 1)

Table 4 shows the dissolved oxygen in the ditch liquor before and after each brush at various immersions of the brushes.

The total amount of dissolved oxygen used up during one cycle is about the same for the 5,6 and 8 inch immersions but less for the 5 inch immersion. This indicates that during the 5 inch immersion there was less nitrification but at the same time available nitrate was being used as a substitute for oxygen. This was

confirmed by no increase in the BOD of the effluent and a decrease in the concentration of nitrate in the effluent.

During the winter months the temperature of the ditch liquor reached a minimum value of + 1.0C°. At that time the outside temperature was -36°C. The ditch had a thin partial ice-cover that extended about 1 foot from each side. However, there was no ice around the brushes and the plant functioned all winter.

The most probable number of coliforms present in the raw sewage and in the plant effluent was determined in lactose broth according to Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1965). Three series of five tubes were inoculated for each dilution. The effluent was diluted $1{:}10^2$, $1{:}10^3$, and $1{:}10^4$. The raw sewage was diluted $1{:}10^4$, $1{:}10^5$ and $1{:}10^6$. These samples had not been chlorinated.

The lowest and the highest effluent counts were respectively 140 and 16,090 coliforms per ml. If these two values were excluded, the counts ranged from 330 to 5420 coliforms per ml, and the average of 22 determinations was 1091 cells per ml.

The coliform counts of the raw sewage varied between 0.8×10^4 and 24×10^4 cells per ml. The average value of 23 determinations was 6.9×10^4. The percentage removal of coliforms varied from 80 to 99.8 percent with an average of 98.5 percent.

From September 2, 1965, through April 25, 1966, 108 specimens were collected, 56 of the specimens tested were influent raw sewage and 52 specimens were effluent discharged into a stream. From the influent specimens, nine (9) yielded thirteen (13) salmonella on culture and nineteen (19) yielded twenty-four (24) viruses. These was no single predominant salmonella in the influent, however, the poliovirus was isolated from 13 of the 19 specimens yielding viruses. The predominance of poliovirus in the influent was due to the feeding of oral polio vaccine (live attenuated virus) to the population. The community immunization

program began November 5, 1965. In contrast to the number of both salmonella and virus isolations from the influent only one salmonella was isolated from 52 effluents tested and six (6) viruses were isolated from six (6) of the 52 effluent specimens. There was no predominating virus type among the six viruses isolated. It is obvious from these data that considerably fewer salmonella and viruses are found in the effluent, one and six respectively, as compared to the thirteen (13) salmonella and twenty-four (24) viruses isolated from the influent.

The oxygen input for the oxidation ditch in Glenwood is done with a stationary cage rotor, and the amount of dissolved oxygen is controlled by varying the liquid level of the ditch. The higher the level of the ditch i.e.: the greater the immersion of the rotors, the more dissolved oxygen is obtained in the ditch liquor. Nitrification increases with increasing dissolved oxygen, and denitrification becomes significant only when the oxygen level becomes very low and increases with an increase in nitrate concentration. The desirable condition is therefore one of enough dissolved oxygen for formation of nitrate, but not so much as to inhibit denitrification. This is obtained by having a high concentration of dissolved oxygen after the rotors, and near zero concentration for some distance before the rotors.

Due to excessive infiltration in the sewer system, the Glenwood plant has been receiving about twice the amount of water expected for a city this size. For that reason we have been unable to control the liquor level of the ditch, which as a result has been too high. As a result of this, the dissolved oxygen has been higher than desired and we have not been able to control the nitrification and the denitrification process. Due to the infiltration the raw sewage has been very weak during the entire study and the BOD of the raw sewage has only exceeded 100 ppm a few times. In view of this fact it should be remembered that dilute sewage is more difficult to treat than normal strength sewage. In addition to

the above mentioned difficulties, the heavy infiltration decreased the detention time in the final settling tank and this interfered with the satisfactory settling of the activated floc. To improve this situation we had to reduce the amount of solids that is normally carried in the ditch.

The city of Glenwood is now in the process of surveying and repairing the infiltration into the sanitary sewer system. One leak flowing at a rate of about 50,000 gallons per day has recently been fixed and if other leaks are found and repaired, more reliable data should be obtained next year.

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FIG. I.

MONTHLY FLOW OF SEWAGE

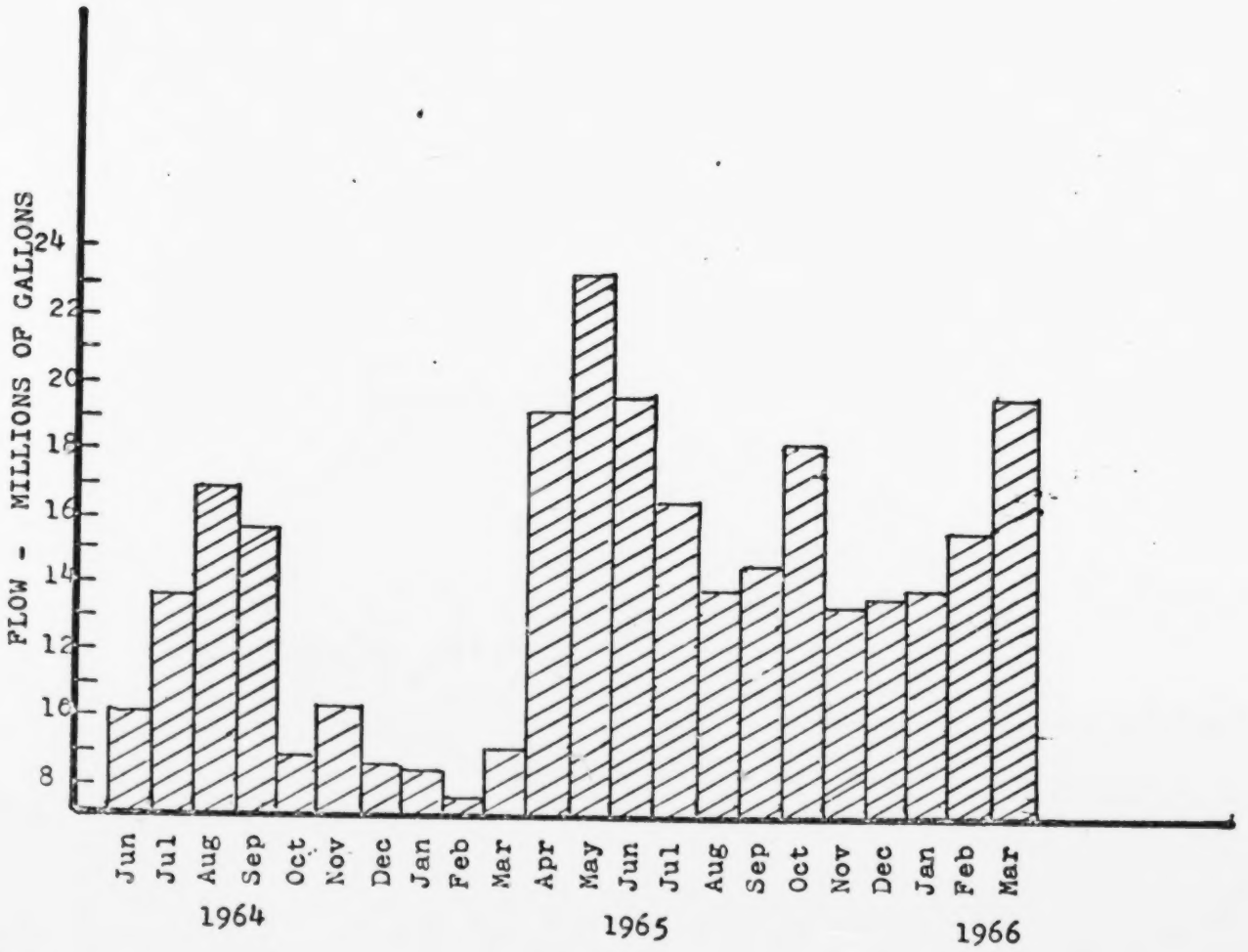

FIG. 2

HOURLY FLOW OF SEWAGE

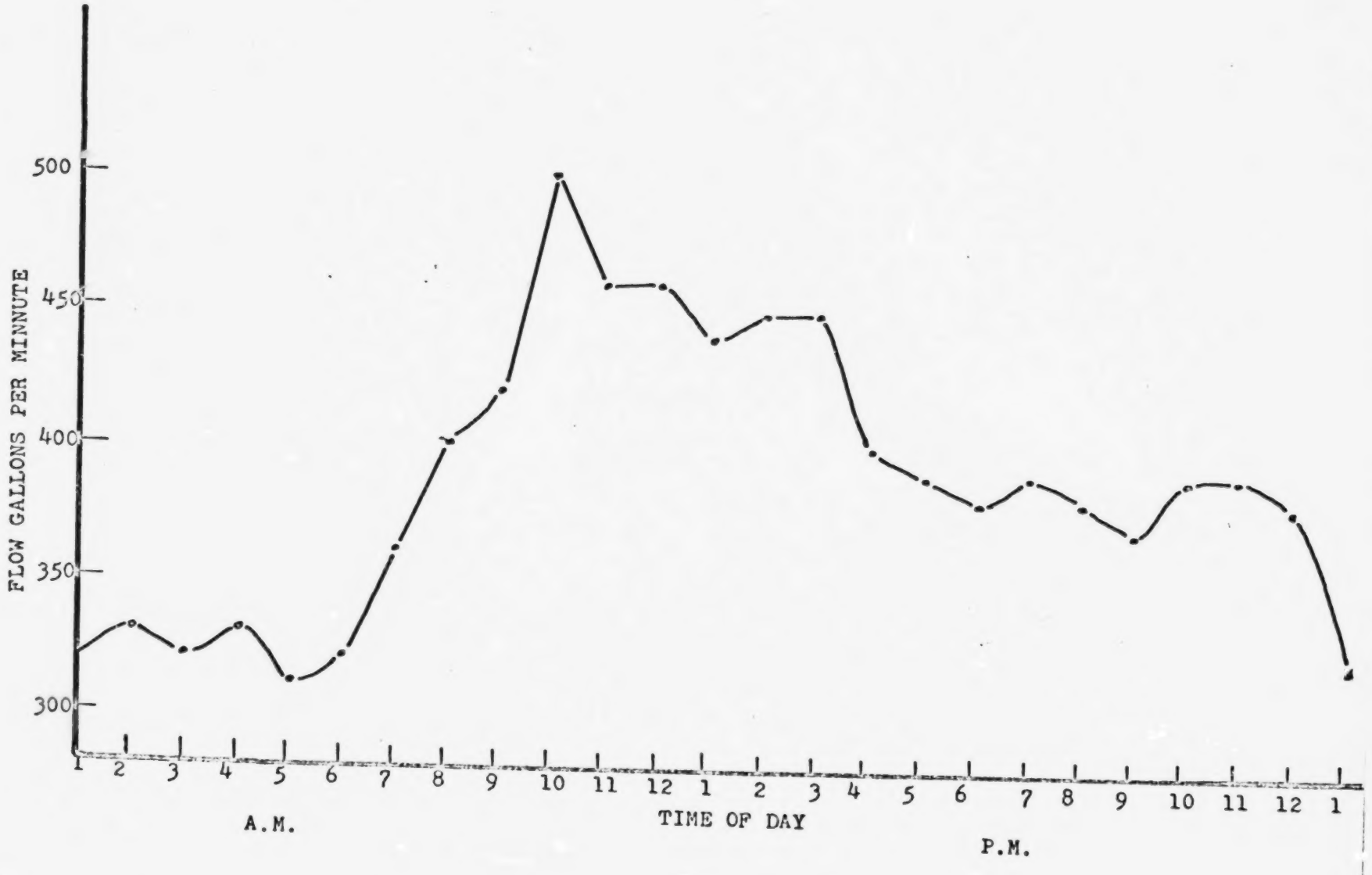

FIG. 3

SEWAGE FLOW vs B.O.D. REMOVAL

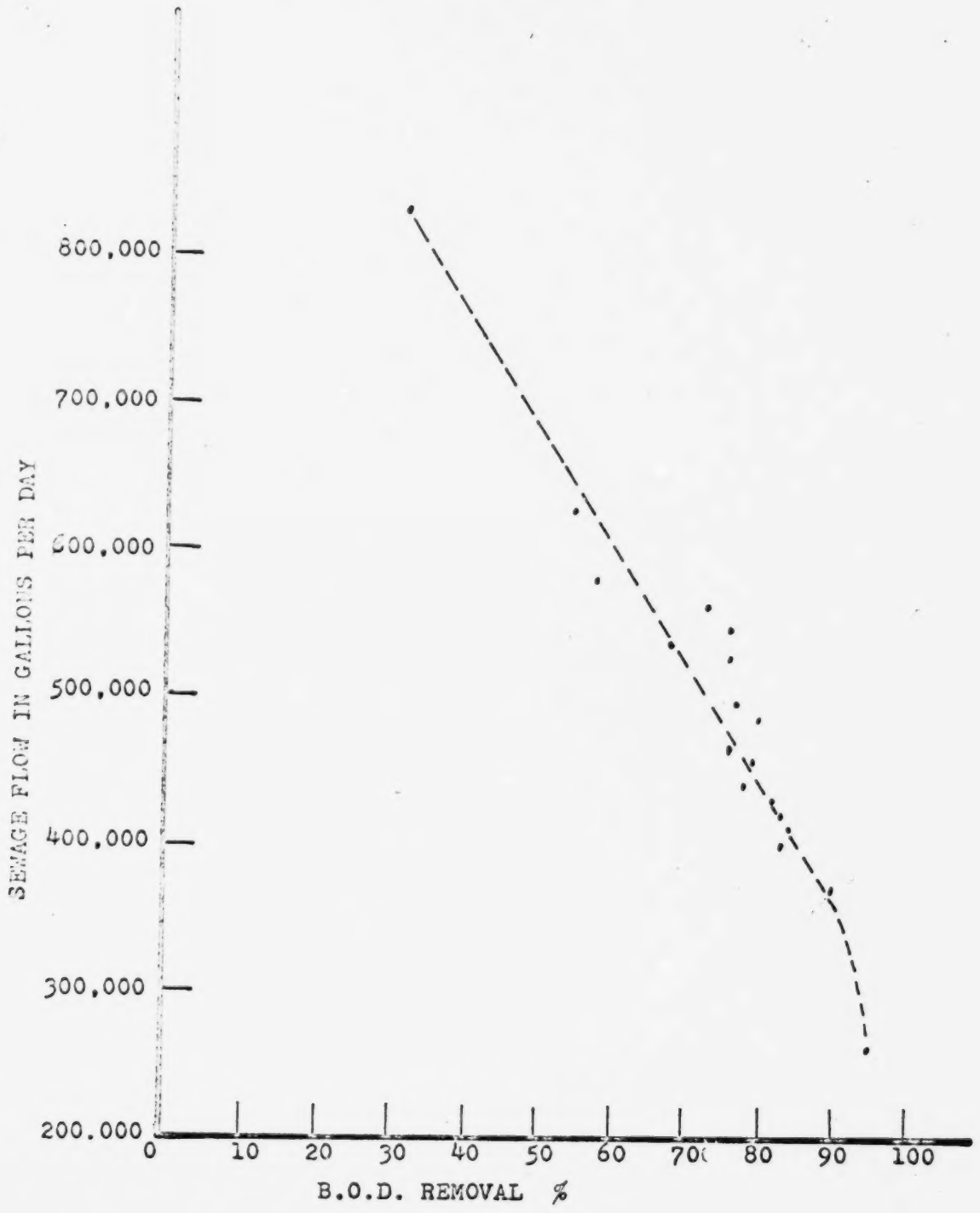

FIG. 4.

AVERAGE NITROGEN REMOVAL PER MONTH

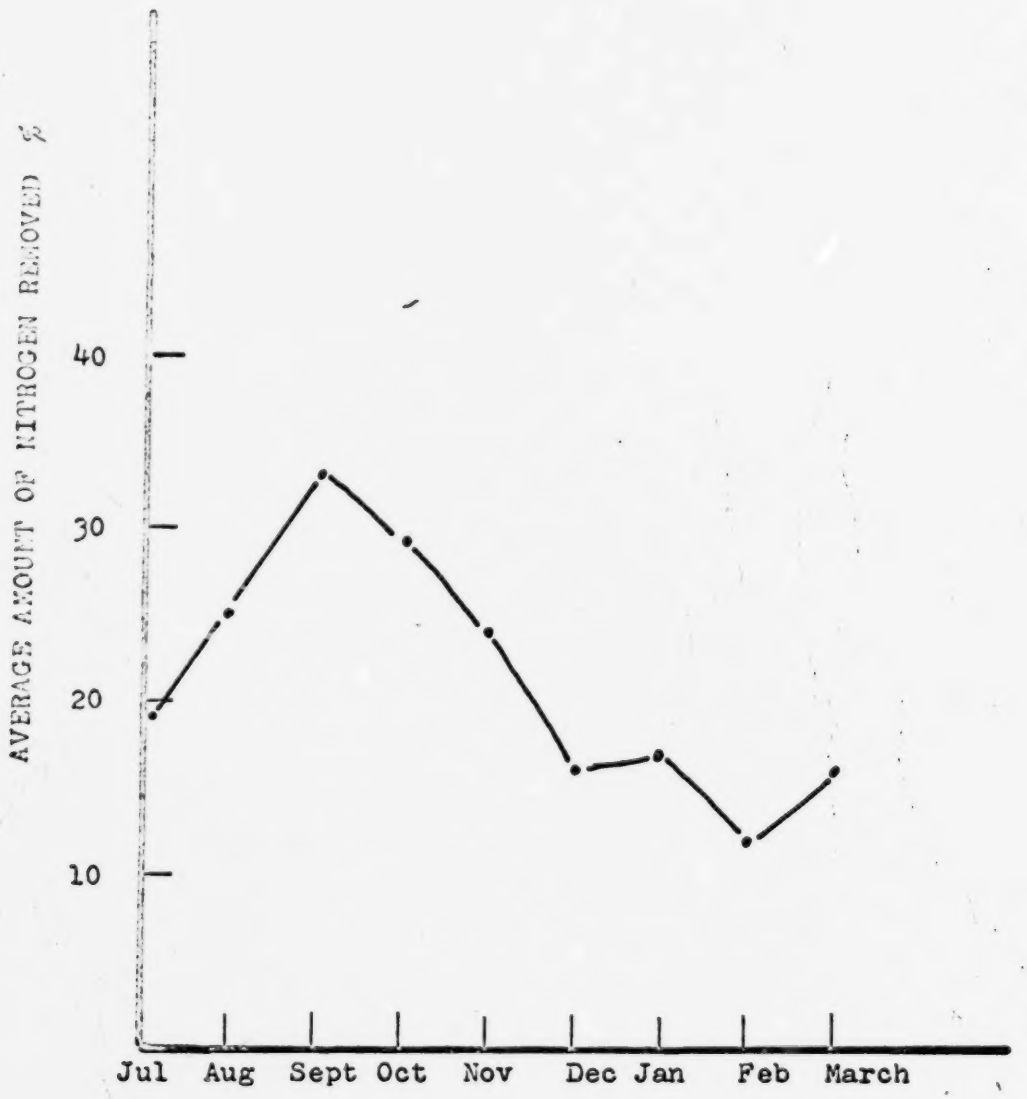

FIG. 5.

DISSOLVED OXYGEN IN DITCH LIQUOR IMMEDIATELY FOLLOWING BRUSH NO. I. AT VARIOUS DEPTHS OF IMMERSION OF THE BRUSH.

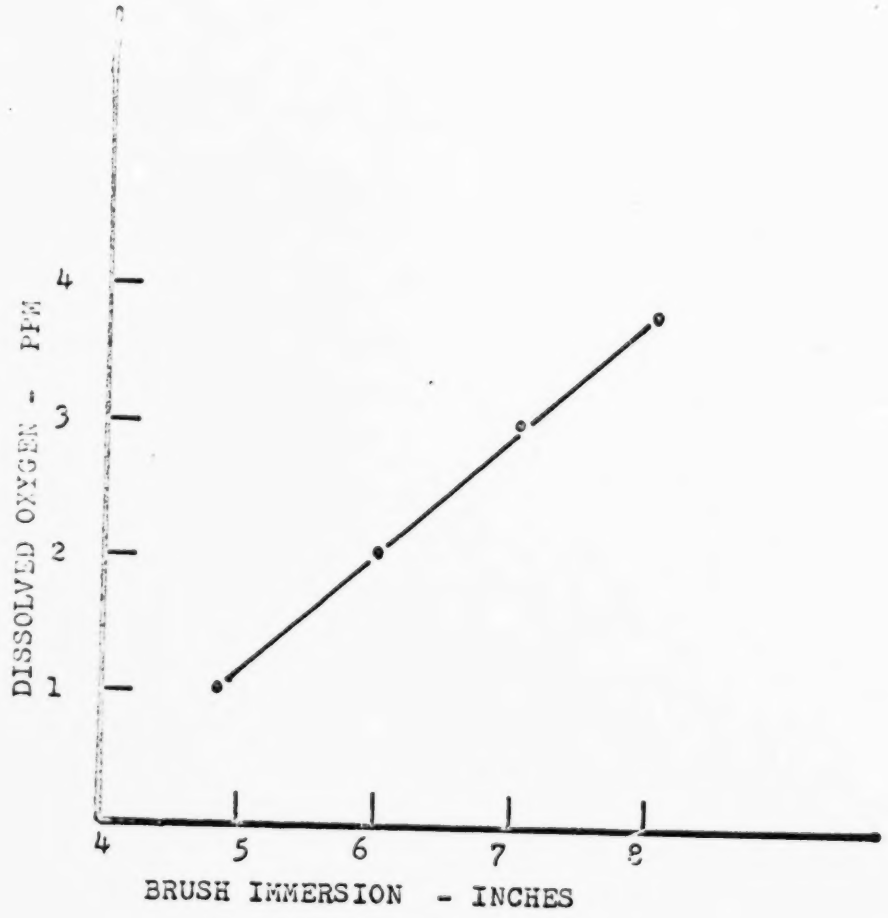

FIG. 6.

DISSOLVED OXYGEN IN DITCH AT VARIOUS DISTANCES FROM BRUSH